Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
WaveSense, Inc. Request for Waiver of	)	Docket No. _____
the Commission's Part 15 Rules	)	
Applicable to Ultra-Wideband Devices	)	

WAVESENSE, INC. REQUEST FOR WAIVER

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WAVESENSE, INC. REQUEST FOR WAIVER

WaveSense, Inc. ("WaveSense") requests a waiver of certain Part 15 rules governing ultra-wideband ("UWB") devices.[1] A waiver is necessary to permit the marketing of WaveSense's driver-assistance safety technology, which relies on UWB ground-penetrating radar ("GPR") to enable active, accurate lanekeeping in otherwise unsafe or unreliable conditions. Since the important safety benefits of WaveSense's UWB GPR technology far outweigh the minimal risk of harmful interference, good cause exists to grant a waiver.[2]

I. WAVESENSE'S UWB GPR TECHNOLOGY IMPROVES SAFE OPERATION OF DRIVER-ASSISTANCE SAFETY TECHNOLOGIES AND AUTONOMOUS VEHICLES.

The safe and reliable operation of driver-assistance technologies—and eventually autonomous vehicles—could improve public health and safety. According to the National Highway Traffic Safety Administration ("NHTSA"), there are over 37,000 traffic deaths and over 2.4 million traffic injuries per year in the United States.[3] It is estimated that "94 percent of

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[1] *See* 47 C.F.R. §§ 15.509(b) (limited field of use) and 15.525 (federal coordination requirements).

[2] *See* 47 C.F.R. § 1.3 ("The provisions of this chapter may be . . . waived for good cause shown"); *see also* 47 C.F.R. § 1.925(b)(3) ("The Commission may grant a request for waiver if it is shown that . . . [t]he underlying purpose of the rule(s) would not be served or would be frustrated by application to the instant case, and that a grant of the requested waiver would be in the public interest.").

[3] *See* NHTSA, "Quick Facts 2016," https://bit.ly/2C0zptv (last visited May 5, 2019).

serious crashes are due to human error"[4] and 52 percent of all fatalities in the U.S. are the result of roadway departures.[5] Driver-assistance technologies and autonomous vehicles present an opportunity to minimize the risk of human error and, by extension, save lives and reduce injuries. To do so, however, these technologies must be capable of operating safely.

While navigation technologies that rely on above-ground data can help these vehicles operate safely, above-ground data cannot be relied on exclusively. Bad weather such as snow or fog can create poor visibility to landmarks used by above-ground navigation technologies. Open roads with few or no surface features make it difficult to determine precise location using above-ground landmarks. Lane markers may be faded, confusing (*e.g.*, at complex intersections), or absent. Additionally, these surface-level conditions can change over time, further complicating vehicles' ability to navigate successfully. Therefore, navigational tools' exclusive reliance on above-ground data make driver-assisted vehicles less safe for everyone.

Subterranean data, however, is largely static and rich with unique features, providing driver-assisted vehicles with a reliable guide by which to navigate. Utilizing UWB GPR, WaveSense's technology leverages these stable data to keep vehicles in lane across different driving conditions and thus increase vehicle safety.[6] WaveSense's UWB technology enables precise vehicle positioning by using downward-facing UWB radar operating between 103-403 MHz to measure and map a road's stable subsurface features (*e.g.*, changes in soil type/density, roots, rock, and cavities). The technology relies on a randomly seeded time offset linear

[4] NHTSA, "Automated Vehicles for Safety," https://bit.ly/2w4Mzrr (last visited May 5, 2019).

[5] FHWA, "Roadway Departure Safety," https://bit.ly/2JNQNrs (last visited July 2, 2019).

[6] WaveSense's technology is intended to complement other existing autonomous vehicle sensors—such as camera, light detection and ranging, Global Navigation Satellite System / Inertial Navigation System, and radar—to assist with lanekeeping functions.

frequency modulated ("LFM") design.[7] When a vehicle with WaveSense's radar technology drives over a mapped road, the radar technology determines its position to centimeter-level accuracy with algorithms that match the radar technology's current scan with previously captured data periodically received from a database.

As the attached Technical Appendix demonstrates, WaveSense's GPR technology will not cause harmful interference to other spectrum users.[8] The technology operates from a downward-facing cavity under an automobile, two feet (or less) off of the ground. As a result, low-level radiation is directed at the ground, with the cavity and automobile's chassis shielding errant radiation. Signals also are transmitted only when a vehicle is moving. WaveSense's GPR technology has been formally tested and complies with the power levels under Section 15.509(d)[9] and 15.509(e). WaveSense's GPR technology accordingly will not cause harmful interference to Global Positioning System ("GPS") devices, in-car receivers, public safety operations, aviation operations, or other spectrum users.[10] Moreover, none of the frequencies

[7] Unlike stepped waveforms, LFM is a traditional ultra-wideband waveform in which the frequency range is continuously swept. The Office of Engineering and Technology ("OET") has provided guidance via the Knowledge Database System that such a waveform meets the definition of ultra-wideband as described in 15.503 and is not subject to the requirement of 15.31(c). *See* Federal Communications Commission, OET Knowledge Database, KDB Publication 908926. WaveSense's implementation of LFM has a fractional bandwidth of about 1.2 (*i.e.*, 2*(403-103)/(403+103) = 1.19).

[8] Technical Appendix at 1-3.

[9] *See* 47 C.F.R. § 15.509(d) ("The radiated emissions at or below 960 MHz from a device operating under the provisions of this section shall not exceed the emission levels in § 15.209."); *see also* 47 C.F.R. § 15.209 (listing 150 µV/m at three meters for operations between 88-216 MHz and 200 µV/m at three meters for operations between 216-900 MHz).

[10] WaveSense notes that Geophysical Survey Systems, Inc. ("GSSI") recently submitted a waiver request for an evaluation kit for a GPR vehicular radar device. *See Office of Engineering and Technology Seeks Comment on Geophysical Survey Systems, Inc. Request for Waiver of Certain Part 15 Ultra-Wideband (UWB) Rules*, Public Notice, ET Docket No. 19-155, DA 19-491 (rel. May 30, 2019). GSSI affirmed that its device, like WaveSense's, would "comply with the GPS-

used by the WaveSense GPR fall within or near a GPS band, and the power of harmonic emissions are at least three orders of magnitude lower than the Part 15 emission limits for GPS bands (the measurement was likely limited by the noise floor of the measurement equipment and not the actual emissions of the GPR), further ensuring against any potential risk of harmful interference to GPS receivers.

II. WAIVER OF CERTAIN PART 15 RULES WOULD SERVE THE PUBLIC INTEREST BY PROMOTING INNOVATION AND PUBLIC SAFETY IN DRIVER-ASSISTANCE TECHNOLOGY AND AUTONOMOUS VEHICLE NAVIGATION.

The Commission may grant requests for a waiver under Section 1.3 of its rules if the petitioner demonstrates good cause.[11] Good cause exists "where particular facts would make strict compliance inconsistent with the public interest."[12] "To make this public interest determination, the waiver cannot undermine the purpose of the rule, and there must be a stronger public interest benefit in granting the waiver than in applying the rule."[13]

WaveSense seeks a waiver of Sections 15.509(b) and 15.525 of the Commission's rules.[14] As demonstrated below, good cause exists to grant a waiver because strict application of the above-listed rules would be inconsistent with the public interest. A grant would serve the

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band limits in Section 15.509(e)." *See* Reply Comments of GSSI, ET Docket No. 19-155, at 3 (filed July 5, 2019); Technical Appendix at 1-3.

[11] *See* 47 C.F.R. § 1.3. *See also* 47 C.F.R. § 1.925(b)(3)(i) ("The Commission may grant a request for waiver if it is shown that: [t]he underlying purpose of the rule(s) would not be served or would be frustrated by application to the instant case, and that a grant of the requested waiver would be in the public interest.").

[12] *ICO Global Communications (Holdings) Limited v. FCC,* 428 F.3d 264, 269 (D.C. Cir. 2005) (citing *Northeast Cellular Telephone Co. v. FCC,* 897 F.2d 1164, 1166 (D.C. Cir. 1990)).

[13] *Kyma Medical Technologies Ltd. Request for Waiver of Part 15 of the Commission's Rules Applicable to Ultra-Wideband Devices*, Order, 31 FCC Rcd 9705 ¶ 5 (2016) (citing *WAIT Radio v. FCC,* 418 F.2d 1153, 1157 (D.C. Cir. 1969)) ("*Kyma Waiver Order*").

[14] *See* 47 C.F.R. §§ 15.509(b) and 15.525.

public interest by increasing the reliability and safety of driver-assistance technologies and autonomous vehicle navigation, and this public interest benefit outweighs application of the rules to WaveSense's UWB GPR technology. Furthermore, the Technical Appendix shows how waiver here will not undermine the rules' purpose, which is to "ensure that UWB GPR devices do not cause harmful interference to authorized radio services, including Federal services."[15]

A. Request for Waiver of Limited Fields of Use Specified in Section 15.509(b).

Section 15.509(b) limits operation of GPR technology to "law enforcement, fire fighting, emergency rescue, scientific research, commercial mining, or construction."[16] The Commission, however, has recently waived this limitation to allow use of GPR in commercial agricultural equipment.[17] The Commission found that a waiver would serve the public interest because the commercial device "pose[d] no greater risk of causing harmful interference to authorized users . . . than those devices already permitted under the existing rules" and would allow "innovative uses of GPR technology that will benefit the public through improved farming operations and higher crop yields."[18]

Here, waiver of Section 15.509(b) would enable an equally innovative use of GPR—improved lanekeeping technology for safe, reliable driver-assist and autonomous vehicle operation. As described above and shown in the Technical Appendix, WaveSense's technology presents low risk of interfering with other licensed operations. Therefore, waiver of the UWB

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[15] *Proceq USA Inc. Request for Waiver of Part 15 of the Commission's Rules Applicable to Ultra-Wideband Devices*, Order, 33 FCC Rcd 2258, ¶ 2 (OET 2018).

[16] 47 C.F.R. § 15.509(b).

[17] *See Headsight, Inc. Request for Waiver of Part 15 of the Commission's Rules Applicable to Ultra-Wide Band Devices*, Order, 32 FCC Rcd 1511 (OET 2017).

[18] *Id.* ¶ 1.

use-case restriction outlined in Section 15.109(b) would not undermine its purpose, and a waiver is in the public interest.

B. Request for Waiver of the Coordination Requirements of Section 15.525.

1. WaveSense's GPR technology is unlikely to cause harmful interference, obviating the need for coordination.

Section 15.525 requires an operator of a UWB imaging system to coordinate with federal users through the FCC before the equipment may be used.[19] The Commission adopted the coordination requirement for imaging devices in response to the National Telecommunications and Information Administration's request to protect potentially affected federal government operators providing safety-of-life services.[20] The Commission later stated that this requirement was "primarily put in place to keep track of ground penetrating radars that would potentially be used for extended periods in outdoor locations."[21]

When the Commission implemented its UWB rules, it acknowledged that "[o]ne of the largest potential outdoor uses of UWB technology is vehicular radar" but also made clear that it "d[id] not believe . . . the proliferation of such devices will result in increased interference concerns at the emission levels and frequency range being adopted."[22] As discussed above, WaveSense's GPR technology will comply with these emission levels and the Commission's initial belief when it adopted its UWB rules. As WaveSense's GPR technology is unlikely to cause harmful interference to federal and non-federal spectrum users, the purpose of the

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[19] 47 C.F.R. § 15.525. GPR falls within the definition of "imaging systems." 47 C.F.R. § 15.503(e).

[20] *See Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems,* First Report and Order, 17 FCC Rcd 7435, ¶ 19 (2002) ("[W]e are implementing a coordination requirement for imaging devices, as requested by NTIA.") ("*UWB First Report and Order*").

[21] *Kyma Waiver Order* ¶ 19.

[22] *UWB First Report and Order* ¶ 194.

coordination rule would not be frustrated by grant of a waiver. Given the public interest benefits of WaveSense's GPR technology, a waiver of Section 15.525 is appropriate.

2. In the alternative, the Commission should permit WaveSense to coordinate use of its GPR technology on a one-time basis.

When it implemented its UWB rules in 2002, the Commission stated that use of GPR in vehicles likely would *not* increase harmful interference because of the strict emissions limits. Should the Commission now feel differently—and as an alternative to waiving the coordination requirements of Section 15.525—WaveSense requests that it be considered the "operator" required to coordinate with the FCC under Section 15.525 and, on a one-time basis, coordinate use of its technology with the FCC.[23]

Individual operators of driver-assisted and autonomous vehicles that utilize WaveSense's GPR technology cannot reasonably be expected to coordinate with the Commission when they use their vehicles to travel. Application of Section 15.525 to individual vehicle operators would represent an extreme administrative burden for both the operators and the Commission, which would render this innovative application of GPR commercially unfeasible. While good cause exists to grant a waiver of Section 15.525, should the Commission determine federal coordination is required, WaveSense believes that it is best positioned to serve as the "operator" on a one-time basis and comply with any coordination requirements.[24] This condition would

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[23] *See* 47 C.F.R. § 15.525(a) ("UWB imaging systems require coordination through the FCC before the equipment may be used. The operator shall comply with any constraints on equipment usage resulting from this coordination.").

[24] Under this approach, WaveSense will submit to OET's Frequency Coordination Branch the geographic areas of operation for WaveSense's GPR devices. *See id.* § 15.525(b); *Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems*, Memorandum Opinion and Order and Further Notice of Proposed Rulemaking, 18 FCC Rcd 3857, ¶¶ 30-31 (2003) ("[T]he coordination report associated with a GPR or with a wall imaging system may simply list the geographical area(s). . . . A company using these [mobile imaging

make the coordination requirement administratively feasible without jeopardizing the technology's commercial prospects.

III. CONCLUSION

Waiver of the Part 15 rules discussed above is necessary to permit the marketing of WaveSense's vehicle safety and navigation technology, which relies on UWB GPR to enable active, accurate lanekeeping in otherwise unsafe or unreliable conditions. By improving driver-assisted and autonomous vehicle safety, WaveSense's UWB GPR technology serves the public interest. Furthermore, WaveSense's compliance with other strict UWB rules will ensure that waiver of the requested Part 15 rules will not undermine the rules' purpose. Waiver is therefore appropriate under the Commission's standards and precedents, and the Commission should grant such waiver as expeditiously as possible.

Respectfully submitted,

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systems] likely will operate them over several counties, or even over several states or country-wide.").

Technical Appendix

This Technical Appendix describes four scenarios that were studied based on discussions with staff members of the Federal Communications Commission, the Department of Defense, and the Department of Transportation, including: (1) constructive interference from multiple emitters with receivers inside vehicles, such as those that may be used by public safety land mobile users ("aggregate interference"); (2) interference from vehicles traveling on bridges above roads; (3) interference with aviation operations (*e.g.*, GPR operations on roads near airports or underneath runways); and (4) interference with GPS systems. Based on WaveSense's analysis, there is minimal risk of harmful interference in any of these scenarios, as detailed below.

(1) Aggregate Interference

There is an extremely low potential for aggregate interference from multiple vehicles in close proximity. WaveSense analyzed the worst-case traffic scenario, consisting of small cars on a highway in a traffic jam, which would approximate emitters five meters apart in length and three meters apart in width. Using very conservative assumptions, this simulation assumed that (1) each GPR radiates isotropically at the Part 15 limit, (2) there were no obstructions between the emitters (*i.e.*, "line-of-sight"), (3) there was no attenuation from the ground, cavity, or the vehicle, and (4) all radiation had the same polarization. With these assumptions, when two cars emit at the same frequency at the same time, there would be areas where their emissions may add in-phase and areas where the emissions are out-of-phase.

This simulation addressed the results of multiple devices adding in-phase at the same time. If a receiver had a bandwidth of 120 kHz,[1] then a WaveSense GPR would be in its bandwidth 0.04% of the time.[2] A narrower receive bandwidth would result in a lower chance for interference. Another emitter will only interfere if it is at the same frequency at the same time, and there is a 0.04% chance of this occurring at any time, assuming they are started at random times. The probability of n emitters all on the same frequency at the same time is $(0.0004)^{(n-1)}$. Here, for simplicity and to be conservative, we assume that if two emitters are within 120 kHz of each other, they are at the same frequency.

If two or more emitters do happen to be on the same frequency at the same time, the receiver will only be affected while they are in the same 120 kHz band, which would only be 0.25 µs with the proposed waveform. These results can be used to calculate the likelihood that this will reoccur. The result for four or more cars with ten or more overlapping emissions in ten minutes is 1 occurrence expected in 500,000,000 years, meaning this statistically is extremely unlikely.

The case of four emitters on the same frequency at the same time was simulated with the assumption that the receiver is 1 meter above the GPR and with a far-field approximation. The four emitters were spaced as close as four small cars could be, and the radiation pattern depends on the phase relation between the emitters. Varying this phase relation showed a typical increase

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[1] For example, Public Safety Pool and Industrial/Business Pool channel authorizations are for bandwidths of 12.5 kHz or less. 47 C.F.R. § 90.173(l).

[2] 120kHz/300MHz = 0.04%.

of 3.9 dB above Part 15 standards in the very unlikely event that four emitters constructively interfere, although the unlikely theoretical maximum is the phase-aligned sum of the fields.

(2) Interference from Vehicles on a Bridge

To analyze potential interference from vehicles on a bridge, we modeled a bridge in ANSYS's HFSS software, a full-wave simulator, to find the worst-case gain from the antenna through the bridge.[3] To be conservative, no attenuation was modeled from the large supports under the bridge, just the deck layer. Assuming the distance between the emitter and the receiver is 5 meters (*i.e.*, the bridge is 5 meters high including all support structures, a conservative estimate),[4] the maximum radiation was found to be 53 dBμV/m, the equivalent of the Section 15.209 standard at a distance of 1.25 meters, which is within the norms of a typical Part 15 device.[5]

(3) Aviation Interference

The third simulation evaluated if a sensor on a highway near an airplane could cause interference. The Atlanta airport has a tunnel running under a runway.[6] The runway is 20 meters higher than the highway, and at that distance, the maximum Part 15 emissions are 26 dB below the 15.209 standard at 3 meters.[7]

Another potential concern is a runway near a highway, instead of overhead. The line-of-sight from the highway to an airplane at the Atlanta airport is 180 meters.[8] The additional 177 meters to the 3 meters distance of the 15.209 standard provides an additional 45 dB of loss.

In both cases, emissions were so far below the Part 15 standard that interference does not appear probable.

(4) Aggregate GPS Interference

Because GPS is critical to a number of technologies, including autonomous vehicles, none of the frequencies used by the WaveSense GPR fall within or near a GPS band, and we have measured

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[3] *CDOT Bridge Design Manual, Section 9: Deck and Deck Systems*, Colorado Dept. of Transp. (Jan. 2019), *available at* https://bit.ly/2YecfiN.

[4] Mitigation Strategies For Design Exceptions: Vertical Clearance, Federal Highway Administration, https://bit.ly/2Gm2Qv6 (last modified Apr. 1, 2019).

[5] 47 C.F.R. § 15.209(a).

[6] Equipment World, *Atlanta runway bridge being built over interstate*, Randall Reilly Construction (Mar. 25, 2004), *available at* https://bit.ly/30RzlJD.

[7] 47 C.F.R. § 15.209(a).

[8] Hartsfield-Jackson Atlanta International Airport, Google Maps, https://bit.ly/2JHMa3n (last visited July 22, 2019).

the power of harmonic emissions to be at least three orders of magnitude lower than the Part 15 emission limits into GPS bands.[9]

To address any possibility that aggregate harmonic emissions could cause interference in the GPS bands, WaveSense funded anechoic chamber measurements at GPS frequencies at considerable added expense. These measurements showed that the system emissions from a single emitter at GPS frequencies were at least 29 dB below the Part 15 emissions standard. This means that multiple emitters in aggregate would still produce peak emissions that are several orders of magnitude below the Part 15 standard for a single emitter; and as shown in the aggregate scenario above, it is highly improbable that a large number of emitters will be emitting at the same frequency at the same time. Further, this measurement was likely limited by the noise floor of the measurement equipment and not the actual emissions of the GPR, which may have been significantly lower.

[9] *See* 47 C.F.R. § 15.509(e).